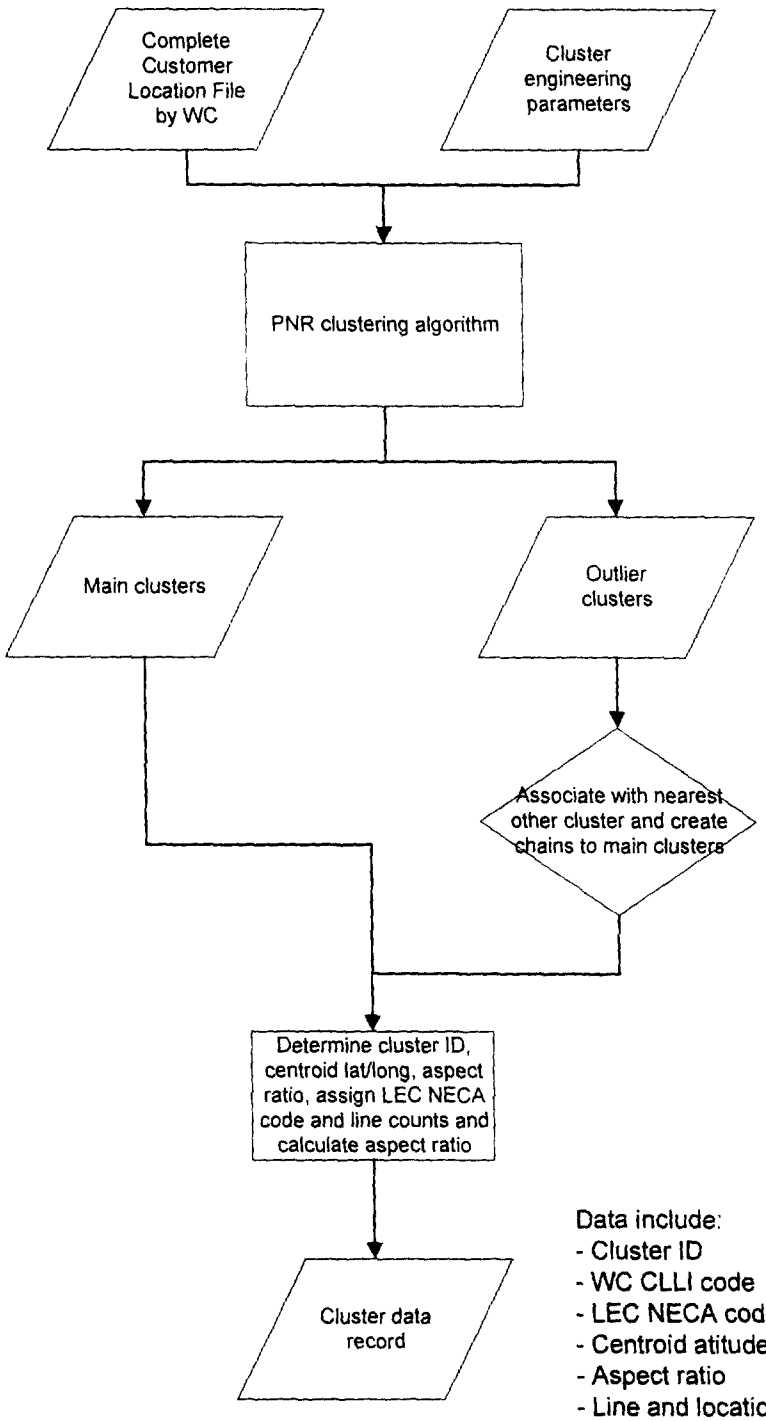
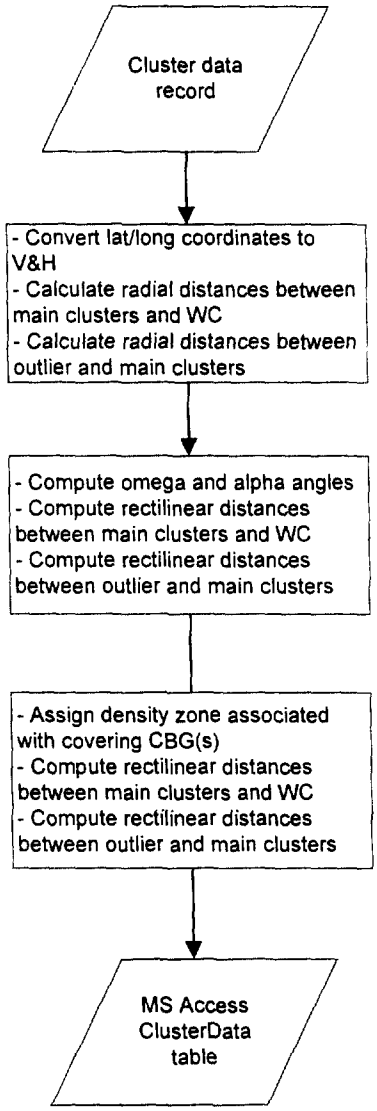
CLUSTERING PROCESS



Data include:
- Cluster ID
- WC CLLI code
- LEC NECA code
- Centroid atitude and longitude
- Aspect ratio
- Line and location counts
- Identity of nearest other cluster

"POINTCODE" PROCESSES



Data include:
- 2-character state code
- 8-character CLLI
- LEC name and NECA code
- Covering CBG ID
- Alpha, omega and radial distance
- Area, aspect ratio, lines density
- Terrain characteristics
- Line, household and housing unit counts
- Firm and employee counts

Appendix D

General Rules Governing the Creation of the HM 5.0a Distance Files

General Rules Governing the Creation of the HM 5.0a Distance Files

1) Three distances are computed for each wire center (WC). They include WC to tandem WC to OS tandem, and WC to STP locations.

2) The SLED is the official data source for computation of the distance files.

3) BOC WCs home on the nearest BOC tandems and BOC STPs in the same state and LATA. There are some cases where LATA boundaries cross state lines. In this case, BOC WCs will first attempt to home on a tandem or STP in the same state and LATA where the WC is physically located. However, if tandems or STPs do not exist in the same state as the WC, then the WC will home on the nearest BOC tandem and STP pair.

4) Independent WCs will home on the nearest independent tandems and independent STPs in the same state, when such tandem/STP facilities are available. When independent tandem/STP facilities are not available, independent WCs will home on the nearest BOC wire center. In cases where independent wire centers home on BOC wire centers (any of which always have tandem, OS tandem, and STP connectivity), the CLLI of the homed-on BOC wire center will be tracked. LATA boundaries are meaningless when making ICO distance computations.

5) The set of eligible BOC tandems will be the same set used to compute distances in HM 3.1, with the following adjustments: 1) non-ILEC tandems will be removed from the HM 3.1 list of tandems and STPs; and 2) in most cases, at least one BOC tandem/STP pair will be placed in each LATA (in HM 3.1 there were some LATAs without BOC tandems or STPs). The set of eligible independent tandems will consist of all existing independent tandems in the study state.

6) BOCs will be limited to one OS tandem per state in small states (determined by population) and two OS tandems in large states. The set of OS tandems will be hand-selected from the list of current OS tandem locations in the study state. Independent tandem distances will be computed based on the current locations of all independent OS tandems.

7) BOCs will be limited to a single STP pair per LATA. The set of independent STPs is the set of all independent STP pairs in the study state. Embedded STP *pairing* relationships will be maintained for BOCs and independent companies. Note that embedded STP *homing* relationships are not maintained. LATAs without any STP pairs will be assigned a hand-selected pair of wire centers to serve as the STPs. Hand-selection is rare and only occurs in a few areas (i.e., Alaska, Puerto Rico, etc.).

8) There are several cases that must be specifically addressed when creating the distance database. Although these cases are discussed in items 3 and 4 above, they are individually presented here for clarity. The same set of rules apply whether determining distances from WCs to tandems, OS tandems, or STPs. These cases are identified immediately below.

- Case 1: For BOC companies, WC is in the same LATA, same state, and has the same OCN as at least one tandem. The action in this case is to determine the path length to the nearest tandem in this state and LATA, with the same OCN.
- Case 2: For BOC companies, WC is in a different LATA than any BOC tandems in the state. In this case, determine the path length to the nearest BOC tandem in this state. If such a WC belongs to a different BOC than the predominant BOC in the state, the same rule applies.
- Case 3: For ICOs, the WC has a different OCN than any tandem in the state. The action in this case is to determine the path length to the nearest BOC wire center in this state and track the CLLI code of the homed-on BOC wire center.
- Case 4: For ICOs, the WC is in the same state and has the same OCN as at least one tandem. The action in this case is to determine the path length to the nearest tandem in this state with the same OCN.

9) Distances between facilities are computed as right angle runs.

10) WC to STP distances will be computed as the total distance from the WC to each STP in the pair.

11) In cases where one member of the STP pair lies outside of the study state, the distance to the one STP in the state will be doubled as a proxy for the out-of-state STP. Proxy STP pairs will only be used in cases where an actual STP pair is unavailable.

12) Tandem to tandem distances will be computed as a fully-interconnected mesh network of all tandems with the same OCN. BOC tandems will interconnect within LATA boundaries.

Distance File Contents

The following calculated and non-calculated information will be contained in the state-specific distance files:

Calculated Information

1) The WC to tandem homing arrangements that result from the application of the rules defined in this memo. This information is necessary when computing interoffice ring distances.

2) The WC to tandem distance.
3) The WC to STP (A-link) distance.
4) The WC to OS tandem distance.
5) The STP to STP (C-link) distance.
6) The number of tandems by company code.
7) The number of STP pairs by company code.
8) The tandem to tandem distance for a fully-interconnected mesh of tandems by company code.
9) The total tandem to STP (A-link) distance by company code.

Non-Calculated Information

Non calculated information include the NECA data that is necessary for interoffice ring calculations. These data are included for each CLLI in the study state.

1) Vertical coordinate
2) Horizontal Coordinate
3) NECA Company code

Additional Information

The distance file calculations require the following database fields, which are taken from the indicated source.

Field	Source
- LATA	SLED
- OCN	SLED
- CLLI	SLED
- STATE	SLED
- VERTICAL COORDS	SLED
- HORIZONTAL COORDS	SLED
- STP PAIRS	LERG
- OS TANDEM INDICATOR	SLED
- LOCAL TANDEM INDICATOR	SLED
- STUDY STATE	USER INPUT
- BOC OCN	USER INPUT

Appendix E

Equation Listings for the HM 5.0a Network Engineering Logic Modules:

Distribution

Feeder

Switching and Interoffice

Workbook: **R50A_distribution.xls**
Worksheet: **cluster input data**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
A	wire center	The data for this sheet is taken from the ClusterData table in the access database.	
B	company		
C	operating company type		
D	CBG geocode		
E	cluster		
F	overall quadrant		
G	overall omega		
H	overall alpha		
I	overall radial dist ft		
J	outlier indicator		
K	cluster quadrant		
L	cluster omega		
M	cluster alpha		
N	outlier radius, ft		
O	area, sq mi		
P	aspect ratio		
Q	spare		
R	density, lines/sq mi		
S	Rock Depth		
T	Rock Hrdns		
U	Surf Tex		
V	Wtr Tbl Dpth		
W	tot lines		
X	total business lines		
Y	residential lines		
Z	special access		
AA	public		
AB	single-line business		
AC	households		
AD	1-hu detach		
AE	1-hu attach		

Workbook: **R50A_distribution.xls**
Worksheet: **cluster input data**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
AF	hu-2		
AG	hu-4		
AH	hu-5-9		
AI	hu 10-19		
AJ	hu-20-49		
AK	hu-50+		
AL	mobile		
AM	other		
AN	businesses		
AO	employees		
AP	cluster fraction of wire center lines		
AQ	average outlier loop length		
AR	total outlier lines		

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
A	CBG	='cluster input data'!D2	repeats principal CBG for cluster
B	cluster	='cluster input data'!E2	repeats cluster or outlier ID from cluster input data
C	Main feeder distance (ft)	=IF(P2=0,'cluster input data'!I2*COS(PI()/180*DM2)*IF(diff_sfc>1,dstnc_mult,1),0)*IF(fdr_steer_enable,fdr_rtc_air,1)	Distance along main feeder route from wire center to point at which subfeeder cable departs to connect with cluster; includes adjustments for difficult surface routing increase, if selected, and for route/air ratio, if feeder steering enabled
D	Basic subfeeder distance (ft)	=IF(P2=0,'cluster input data'!I2*SIN(PI()/180*DM2)*IF(diff_sfc>1,dstnc_mult,1),0)	perpendicular distance from main feeder route to center of cluster, adjusted for difficult surface rerouting, if selected
E	Total feeder distance (ft)	=C2+D2	Calculates sum of main and subfeeder distance for cluster
F	Fiber Indicator	=IF(OR(E2>fiber_dist,E2+T2+W2+0.5*AX2+0.5*AW2/U2>max_cu_dstnc,CK2=1,DN2+DP2<DO2),1,0)	Computed value of 1 indicates fiber feeder required for this cluster; fiber required if feeder distance > fiber feeder crossover distance, max distance from wire center to extremity of cluster > maximum allowed copper distance, outliers present, or fiber+DLC costs less than estimated copper feeder life cycle costs
G	aspect ratio	=IF(AND(NOT(rect_clustr_switch),'cluster input data'!P2>0),'cluster input data'!P2,1)	selects input aspect ratio if rectangular cluster calculations are enabled; otherwise, makes clusters square
H	Rock placement multiplier	=IF(rock_hrdns="HARD",hard_plc_mult,soft_plc_mult)	Selects hard rock factor when shown in cluster input data, otherwise inserts soft rock factor for use in calculation of rock multiplier
I	Rock multiplier adjusted for depth	=IF(OR(ISBLANK(rock_depth),rock_depth>bdrock_thresh),1,H2-(H2-1)/bdrock_thresh*rock_depth)	Adjusts rock multiplier linearly with bedrock depth; if bedrock is below placement depth, the factor is unity; at zero depth, the factor is the basic placement factor in column H
J	Difficult surface multiplier	=IF(ISBLANK('cluster input data'!U2),1,IF(ISNA(VLOOKUP('cluster input data'!U2,surf_text,2,FALSE)),1,VLOOKUP('cluster input data'!U2,surf_text,2,FALSE)))	Obtains difficult surface condition placement factor from inputs sheet.
K	Lot frontage, ft	=IF(P2=0,MAX(66,SQRT(0.5*O2)),0)	Computes lot frontage in feet from average lot size using assumption that depth is twice the frontage. Minimum value is 66 feet
L	lot depth, ft	=2*K2	computes lot depth as twice the frontage

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
M	Households	='cluster input data'!AC2	repeats household count from cluster input data
N	Businesses	='cluster input data'!AN2	Repeats total business line count from cluster input data
O	Average cluster lot size, sq ft	='cluster input data'!O2/Q2*5280^2	Computes average lot size from cluster area in cluster input data and computed estimate of subscriber locations within cluster
P	outlier indicator	=IF('cluster input data'!J2=1,1,0)	indicates whether record pertains to cluster or outlier
Q	Total locations	=hh_det+0.5*(hh_att+hh_2+hh_4+hh_59+hh_1019+hh_2049+hh_mob+hh_other+firms)+hh_50/4	Estimates effective number of subscriber locations by weighting different housing types
R	Lines	=lines_adj	total lines, including special access, in cluster or outlier
S	backbone length divisor/RT multiplier	=MAX(1,CEILING((MAX(0,2640*SQRT(clustr_area*aspect)-depth)/(max_cu_dstnc/(1+1/aspect))),1))	backbone cable length divisor, normally unity, computed whenever backbone distance exceeds one-half the user-set maximum cable distance; used to ensure copper distances do not exceed maximum; application divides the length of each backbone cable and increases the number of cables (there are normally two)
T	Backbone cable length	=IF(AND(P2=0,V2>2),MAX(0,2640*SQRT(clustr_area*aspect)-depth)/S2,0)*IF(diff_sfc>1,dstnc_mult,1)	Computes backbone cable distance as distance from center of cluster to point one lot depth from cluster boundary; includes adjustment for aspect ratio if enabled, allowing rectangular clusters
U	branch length divisor/RT multiplier	=MAX(1,CEILING((MAX(0,2640*SQRT(clustr_area/aspect)-front_lot)/(max_cu_dstnc/(1+aspect))),1))	branch cable length divisor, normally unity, computed whenever branch distance exceeds one-half the user-set maximum cable distance; used to ensure copper distances do not exceed maximum; application of factor increases number of branch cables and corresponding shortens each
V	number of branches (per cluster)	=IF(P2=0,CEILING(5280*SQRT(clustr_area*aspect)/(2*depth),1),0)*U2*2	computes the number of branch cables in a cluster; branch cables extend from the backbone to either side to a point one lot width from edge of cluster
W	branch length	=IF(AND(Q2>2,P2=0),MAX(0,2640*SQRT(clustr_area/aspect)-front_lot)/U2,0)*IF(diff_sfc>1,dstnc_mult,1)	Distance from the backbone cable to the edge of the occupied cluster area, less one lot width; includes aspect ratio factor which allows computation of rectangular clusters

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
X	pairs required per branch cable	=IF(AND(P2=0,V2>0),(lines_adj/V2)/VLOOKUP('cluster input data'!$R2,density_inputs,2),0)	Pairs required per branch cable with cable sizing factor
Y	branch cable cross section	=IF(P2=0,INDEX(cable_range,MATCH($X2-Z2*max_cable,cable_range,-1),1),0)	assigned branch cable cross section; if maximum-sized cables are present, this value covers remaining lines not served by maximum cable
Z	number of maximum branch cables	=TRUNC(X2/max_cable)	calculates number of "overflow" branch cables required by cluster
AA	backbone cross section	=IF(P2=0,INDEX(cable_range,MATCH((1/(S2)*V2*0.5*(Y2+Z2*max_cable))-$AB2*max_cable,cable_range,-1),1),0)	assigned backbone cable size; computed from branch cable size and number of branch cables to ensure preservation of binder-group integrity
AB	number of max backbone cables	=TRUNC(1/(S2)*V2*0.5*(Y2+Z2*max_cable)/max_cable)	computes number of backbone "overflow" cables required
AC	Backbone Taper Factor	=IF(V2/(S2*U2)<=2,1,0.5)	factor accounting for tapering of backbone cable when more than two branch cables connect to each backbone cable
AD	effective subscriber road cable distance	=IF(OR(P2=0,Q2<2),0.5280*MAX(SQRT('cluster input data'!O2*aspect),SQRT('cluster input data'!O2/aspect))+MAX(0,5280*MIN(SQRT('cluster input data'!O2*aspect),SQRT('cluster input data'!O2/aspect))-2*VLOOKUP(density,density_inputs,9)))*IF(diff_sfc>1,dstnc_mult,1)	computes length of cable required to serve outlier locations; length computed as the major dimension of the outlier area plus the minor dimension less two drop lengths, adjusted for difficult surface routing if elected by user
AE	required subscriber road cable pairs	=IF(P2=1,(lines_adj)/MAX(1,BQ2)/VLOOKUP('cluster input data'!R2,density_inputs,2),0)	cable pairs, including sizing factor, required to serve subscribers centered on outlier position
AF	subscriber road cable cross section, per cable	=IF(P2=1,INDEX(cable_range,MATCH(AE2-AG2*max_cable,cable_range,-1),1),0)	assigned road cable cross section in addition to any necessary maximum-sized cables
AG	number of max road cables	=IF(P2=1,TRUNC(AE2/max_cable),0)	computes number of maximum-sized road cables
AH	unadjusted road subscriber cable investment	=IF(AND(P2=1,BH2=0),AD2*AG2*max_cable_inv+AD2*VLOOKUP(calculations!AF2,cable_inv,2,FALSE),0)	total road cable investment for outlier without adjustments for aerial, buried, or underground use
AI	effective road T1 cable distance	=IF(P2=1,'cluster input data'!N2*(SIN(PI()/180*'cluster input data'!M2)+COS(PI()/180*'cluster input data'!M2)),0)*IF(diff_sfc>1,dstnc_mult,1)	T1 road cable distance assuming rectangular routing between end points, with difficult surface routing adjustment if elected by user
AJ	required road T1 cable pairs, per cable	=IF(OR(P2=0,AK2=0,BH2=1),0,2*total_T1s/AK2/VLOOKUP('cluster input data'!R2,density_inputs,2))	required cable pairs, including two pairs per T1 on cable and cable sizing factor
AK	number of road T1 cables	=IF(OR(P2=0,BH2=1),0,CEILING(total_T1s/max_T1s_cable,1))	number of T1 cables required; controlled by maximum allowable T1 pairs in cable

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
AL	road T1 cable cross section	=IF(P2=1,INDEX(cable_range,MATCH(AJ2,cable_range,-1),1),0)	assigned T1 cable cross section
AM	unadjusted road T1 cable investment	=IF(AND(P2=1,BH2=0),AI2*AK2*VLOOKUP(AL2,cable_inv,2,FALSE),0)	total T1 cable investment for this outlier, unadjusted for aerial, buried, or underground structure
AN	total unadjusted cable investment	=IF(BH2=1,0,((IF(P2=0,VLOOKUP(Y2,cable_inv,2,FALSE)*W2*V2+AC2*2*S2*U2*T2*VLOOKUP(calculations!AA2,cable_inv,2,FALSE),0)+AH2+AM2+(AC2*2*S2*U2*T2*AB2+Z2*W2*V2)*max_cable_inv)))	total cable investment for cluster or outlier, including branch, backbone (for clusters) and T1 road, and customer road cables (for outliers); connecting cable investment, if any, is computed by feeder module
AO	underground cable inv	=($AN2)*CF2	computes underground fraction of total cable investment using input underground structure fraction
AP	buried cable inv	=($AN2)*CD2*inputs!$C$19	computes buried cable investment, including additional cable investment for filled cable, using computed buried structure fraction
AQ	aerial cable investment	=($AN2)*CE2+BM2	total aerial cable investment computed with calculated aerial structure fraction
AR	total structure distance	=IF(BH2=1,0,IF(P2=1,AI2+IF(CI3<=CI2,0.5*AD2,0)+IF(Q2<2,0,0.5*(5280*MAX(SQRT('cluster input data'!O2*aspect),SQRT('cluster input data'!O2/aspect))+MAX(0,5280*MIN(SQRT('cluster input data'!O2*aspect),SQRT('cluster input data'!O2/aspect))-2*VLOOKUP(density,density_inputs,9)))),2*S2*U2*T2+V2*W2))	computes total structure distance for cluster; for outliers, includes total distance for T1 cables plus one-half the sum of the major outlier dimension and the minor outlier dimension less two drop lengths; for terminal outliers, total also includes one-half the suuscriber road cable distance
AS	pole investment	=IF(OR(BH2=1,'cluster input data'!R2>=inputs!$B$12),0,((1+CEILING(AR2*CE2/VLOOKUP('cluster input data'!R2,density_inputs,8),1))*(pole_inv+pole_labor*((1-wtg_pole_set)+wtg_pole_set*labor_adj)*(rock_mult+diff_sfc-1))))	computes total pole investment, including pole setting, with adjustments for local surface and rock conditions and labor rates
AT	buried placement	=IF($BH2=1,0,AR2*CD2*VLOOKUP('cluster input data'!$R2,density_inputs,7)*(rock_mult+diff_sfc-1)*((1-wtg_excav)+wtg_excav*labor_adj))	computes total buried placement investment, with adjustments for local surface and rock conditions and labor rates
AU	conduit investment	=IF($BH2=1,0,IF(P2=0,(2*S2*U2*$T2*(1+sp_tubes+$AB2)+$V2*$W2*(1+sp_tubes+$Z2)),(AI2+IF(CI3<=CI2,0.5*AD2,0))*(1+sp_tubes+AG2))*CF2*conduit_inv)	computes total conduit investment, including spare tubes
AV	conduit placement	=IF($BH2=1,0,AR2*CF2*VLOOKUP('cluster input data'!$R2,density_inputs,6)*(rock_mult+diff_sfc-1)*((1-wtg_excav)+wtg_excav*labor_adj))	computes total underground placement investment, with adjustments for local surface and rock conditions and labor rates

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
AW	vertical connecting cable length, ft	=IF($P2=1,0,2*U2*(S2-1)*(T2+depth))	optical connecting cable (feeder) used in subdivided backbone cables to connect subfeeder to RTs; investment computed in feeder module
AX	horizontal connecting cable length, ft	=IF(P2=1,0,2*(U2-1)*(W2+front_lot))	connecting cable horizontal optical connecting cable used to connect subfeeder to RTs when branch cables are subdivided; investment computed in feeder module
AY	vertical structure distance, ft	=IF(P2=1,0,2*U2*(S2-1)*(depth))	structure required to support vertical connecting cable; may be shared with backbone structure in certain cases
AZ	horizontal structure distance, ft	=IF(P2=1,0,IF(EVEN(V2)/4<>TRUNC(EVEN(V2)/4),2*(U2-1)*front_lot,AX2))	structure required to support horizontal connecting cable; may be shared with branch structure in certain cases
BA	total required SAI capacity, per SAI	=(3.5*'cluster input data'!AC2+2*('cluster input data'!X2+SA_loops+'cluster input data'!AA2))/(S2*U2)	computes SAI capacity as the sum of the feeder and distribution connections
BB	max SAIs	=IF(BH2=1,0,TRUNC(SAI_cap/max_SAI))	computes number of maximum-sized SAIs required for cluster
BC	SAI size	=IF(OR(P2=1,BH2=1),0,INDEX(SAI_range,MATCH(SAI_cap-BB2*max_SAI,SAI_range,-1),1))	assigns SAI size for determination of investment
BD	SAI investment	=IF(OR(P2=1,BH2=1),0,BB2*max_SAI_inv+VLOOKUP(BC2,SAI_inv,3,FALSE))*S2*U2	computes total SAI investment
BE	max SAIs, high-rise	=IF(BH2=1,TRUNC((SAI_cap)/max_SAI),0)	computes number of maximum-sized indoor SAIs required
BF	SAI size, high-rise	=IF(BH2=1,INDEX(SAI_range,MATCH(SAI_cap-BE2*max_SAI,SAI_range,-1),1),0)	assigns indoor SAI size for determination of investment
BG	SAI investment, high-rise	=IF(BH2=1,BE2*max_SAI_inv+VLOOKUP(BF2,SAI_inv,2,FALSE),0)*S2*U2	computes total indoor SAI investment
BH	high-rise indicator	=IF(AND(P2=0,clustr_area<0.03,'cluster input data'!R2>30000),1,0)	indicates whether high-rise calculations are to be invoked; requires line density > 30,000 lines/sq mi and cluster area < 0.03 sq mi
BI	high-rise factor	=IF(BH2=0,0,('cluster input data'!AC2*1500+'cluster input data'!AO2*200)/((1-inputs!$F$30)*'cluster input data'!O2*5280^2))	estimates number of "floors" using assumed floor areas per household and employees
BJ	number of riser pairs required per cable	=(2*'cluster input data'!AC2+'cluster input data'!AA2+SA_loops+'cluster input data'!X2)/2	computes required cable pairs, including cable sizing factor; two equally-sized cables assumed
BK	number of maximum riser cables	=TRUNC(BJ2/max_riser)*2	computes number of maximum-sized riser cables
BL	riser cable cross section	=INDEX(riser_range,MATCH(BJ2-$BK2/2*max_riser,riser_range,-1),1)	assigns riser cable size

Workbook: **R50A_distribution.xls**
Worksheet: **calculations**

Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
BM	riser cable investment	=IF(BH2=1,(BK2*max_riser_inv+2*VLOOKUP(BL2,riser_inv,2,FALSE))*15*CEILING(MIN(BI2,50),1),0)	computes total riser cable investment; limits building to fifty stories
BN	total T1s required per route	=IF(P2=1,CN2,0)	repeats count of T1s traversing or terminating at current outlier
BO	total repeaters required per cable	=IF(P2=1,CEILING(AI2/(1000*T1_rptr_spcng/(CE2*T1_atten_aerial+(1-CE2)*T1_atten_buried)),1)*BN2,0)	computes repeaters required for T1s in outlier segment by considering aerial and ug/buried structure fractions, number of T1, distance, and allowable cable loss between repeaters
BP	total installed repeater investment per cable	=BO2*repeater_inv	computes total investment in T1 repeaters per cable; multiplied by number of T1 cables in output sheet (AF2)
BQ	road RT indicator/copper distance multiplier	=IF(AND(P2=1,CR2=0),MAX(1,CEILING(AI2/max_cu_dstnc,1)),0)	computes factor to add RTs in outlier distribution if total outlier customer distance exceeds maximum copper distance
BR	total road RTs	=IF(AND(P2=1,BQ2>0),BQ2*CEILING(lines_adj/BQ2/RT_fill/24,1),0)	calculates number of small RTs to serve subscribers assigned to outliers
BS	total installed terminal investment per cable	=IF(AND(P2=1,BR2>0),BR2*(road_RT_inv+road_COT_per_RT_inv)+CU_inv_road*calculations!R2/RT_fill,0)	computes total RT investment, including common equipment and channel units, for outlier
BT	average loop length in cluster	=IF(P2=0,0.5*(T2+W2+AW2/U2+AX2)+E2,0)	estimates average loop length within cluster, including common feeder distance for all cluster lines; includes effects of connecting cable when present
BU	distribution route distance in cluster	=IF(P2=0,2*S2*U2*T2+V2*W2+CQ2,0)	calculates total route, or structure, distance for cluster
BV	maximum loop length in cluster	=IF(P2=0,E2+T2+W2+0.5*(AW2/U2+AX2),0)	calculates maximum loop length within cluster
BW	equivalent SA loops	=sa_lines*(DS0_frac*DS0_pair+DS1_frac*DS1_pair+DS3_frac*DS3_pair)	computes equivalent special access loops for users with access to precise input data concerning types and numbers of multiplexed special access lines in cluster
BX	adjusted total lines	=lines-sa_lines+SA_loops	adjusts input line total for re-computed special access loop total for users having access to precise special access facility data for cluster
BY	number of DLC LD terminals	=IF(OR(P2=1,(R2+CS2)/(S2*U2)>=inputs!$C$105),0,S2*U2*CEILING((R2+CS2)/(S2*U2)/(inputs!$D$96*inputs!$D$97*(1+inputs!$D$110)),1))	computes number of low-density remote terminals required for cluster; includes effects of branch and backbone subdivision, if required

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Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
BZ	LD terminal investment	=IF(OR(P2=1,(R2+CS2)/(S2*U2)>=inputs!$C$105),0,inputs!$D$95+inputs!$D$107+inputs!$D$98*BY2+IF((R2+CS2)/(S2*U2)/inputs!$D$97>inputs!$D$96,CEILING(((R2+CS2)/(S2*U2)/inputs!$D$97-inputs!$D$96)/inputs!$D$96,1)*inputs!$D$109,0)+(CEILING((output!$L2+output!$M2+CS2)/(S2*U2)/inputs!$D$97/inputs!$D$100,1)*inputs!$D$99+CEILING(output!$O2/(S2*U2)/inputs!$D$97/inputs!$D$102,1)*inputs!$D$101))	computes total investment in low-density remote terminals, including site, common equipment, and channel units
CA	number of HD RTs	=IF(OR(P2=1,(R2+CS2)/(S2*U2)<inputs!$C$105),0,S2*U2*CEILING((R2+CS2)/(S2*U2)/(inputs!$C$96*inputs!$C$97*(1+inputs!$C$110)),1))	calculates number of high-density remote terminals to serve cluster; this calculation and that in BY are mutually exclusive
CB	HD RT investment	=IF(OR(P2=1,(R2+CS2)/(S2*U2)<inputs!$C$105),0,inputs!$C$95+inputs!$C$107+inputs!$C$98*CA2+IF((R2+CS2)/(S2*U2)/inputs!$C$97>inputs!$C$96,CEILING(((R2+CS2)/(S2*U2)/inputs!$C$97-inputs!$C$96)/inputs!$C$96,1)*inputs!$C$109,0)+(CEILING((output!$L2+output!$M2+CS2)/(S2*U2)/inputs!$C$97/inputs!$C$100,1)*inputs!$C$99+CEILING(output!$O2/(S2*U2)/inputs!$C$97/inputs!$C$102,1)*inputs!$C$101))	calculates total investment in high-density remote terminal, including site, common equipment, and channel units, as well as CO multiplexing equipment
CC	fiber strands required	=BY2*inputs!$D$106+CA2*inputs!$C$106	calculates number of fiber strands required to serve cluster according to computed RT totals and user-set number of strands per RT
CD	effective buried fraction distribution	=VLOOKUP('cluster input data'!R2,density_inputs,5)+DC2	computes effective buried structure fraction according to local surface and rock conditions
CE	effective aerial fraction distribution	=MAX(0,1-CD2-CF2)	computes effective aerial structure fraction according to local surface and rock conditions
CF	effective u/g fraction distribution	=VLOOKUP('cluster input data'!R2,density_inputs,3)	repeats input underground structure fraction set by user
CG	cluster serial number	=RIGHT(LEFT(B2,SEARCH(".",B2)-1),SEARCH(".",B2)-2)	extracts basic cluster serial number from cluster or outlier ID in cluster input data
CH	outlier number	=RIGHT(B2,LEN(B2)-SEARCH(".",B2))	Extracts outlier extension from cluster ID
CI	outlier order	=IF(P2=1,LEN(CH2)/3,0)	Computes outlier level from outlier number
CJ	outlier root ID	=IF(ISBLANK(CH2),0,LEFT(CH2,3))	extracts number of outlier on which current outlier chain homes
CK	cluster -- attached outlier indicator	=IF(AND(P2=0,P3=1),1,0)	indicates for clusters whether any outliers are attached; used in specifying whether fiber feeder is required
CL	cumulative lines in chain	=IF(ISBLANK(CH2),0,IF(AND(CJ3=CJ2,CG3=CG2),CL3+CU2,CU2))	accumulates line count within outlier chain
CM	number of T1s req'd -- terminal outlier	=IF(P2=0.0,IF(CI3>CI2,0,CEILING(CU2/RT_fill/24,1)))	calculates number of T1s required to serve last outlier in chain

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Equation Listing

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Distribution Module

Column	Name	Formula	Description
CN	number of T1s reqd -- "through" clusters	=IF(CI3<=CI2,CM2,CEILING((CL2-IF(AND(CI2=1,AI2<max_cu_dstnc),CU2,0))/RT_fill/24,1))	computes total of number of T1s required to serve current and subsequent outliers in chain
CO	total T1s in chain	=IF(CI2=1,CN2,0)	
CP	cumulative T1s in cluster	=IF(CG3=CG2,CP3+CO2,CO2)	accumulates number of T1s required to serve all outliers in cluster
CQ	cumulative outlier road distance in cluster	=IF(CG3=CG2,CQ3+AI2,AI2)	accumulates outlier road distance for cluster
CR	first-order outlier lines not on T1	=IF(AND(CI2=1,AI2+0.5*AD2<max_cu_dstnc),CU2,0)	calculates number of lines in first-order outliers (those connected directly to clusters) that lie within maximum copper distance
CS	cumulative first-order outlier lines not on T1	=IF(CG3=CG2,CS3+CR2,CR2)	accumulates non-T1-served first-order outlier lines for cluster
CT	terminal outlier indicator	=IF(AND(P2=1,CI3<=CI2),1,0)	indicates whether outlier is last in chain
CU	outlier lines	=IF(P2=1,R2,0)	repeats total line count for outlier
CV	distribution buried investment/foot, cable + placement, with sharing	=VLOOKUP(IF(P2=0,$Y2,AF2),cable_inv,2,FALSE)*inputs!$C$19+VLOOKUP(density,density_inputs,7)*VLOOKUP(density,density_inputs,19)	calculates buried cable and placement investment per foot, with effect of structure sharing
CW	distribution aerial investment/foot, cable	=VLOOKUP(IF(P2=0,$Y2,AF2),cable_inv,2,FALSE)	calculates aerial cable investment per foot
CX	distribution aerial investment/foot, pole, with sharing	=(inputs!$C$16+inputs!$C$17*inputs!$C$25)/VLOOKUP(density,density_inputs,8)*VLOOKUP(density,density_inputs,18)	calculates aerial structure investment per foot, with effects of structure sharing
CY	std buried LC cost/ft, with sharing	=CV2*(LCFactors!$D$3+LCFactors!$C$3)	calculates life cycle cost per foot of buried cable and structure without effects of local rock and surface conditions
CZ	std aerial LC cost/ft, with sharing	=CW2*(LCFactors!$D$5+LCFactors!$C$5)+CX2*(LCFactors!$D$9+LCFactors!$C$9)	calculates life cycle cost per foot of acrial cable and structure without effects of local rock and surface conditions
DA	local buried LC cost/ft, w/sharing	=(VLOOKUP(IF(P2=0,$Y2,AF2),cable_inv,2,FALSE)*inputs!$C$19+(I2+J2-1)*VLOOKUP(density,density_inputs,7)*VLOOKUP(density,density_inputs,19))*(LCFactors!$D$3+LCFactors!$C$3)	calculates life cycle cost of buried cable and structure, with effects of local rock and surface conditions
DB	local aerial LC cost/ft, w/sharing	=CW2*(LCFactors!$D$5+LCFactors!$C$5)+(inputs!$C$16+(I2+J2-1)*inputs!$C$17*inputs!$C$25)/VLOOKUP(density,density_inputs,8)*VLOOKUP(density,density_inputs,18)*(LCFactors!$D$9+LCFactors!$C$9)	calculates life cycle cost of aerial cable and structure, with effects of local rock and surface conditions

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Equation Listing

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Distribution Module

Column	Name	Formula	Description
DC	buried adjustment	=(0.5-1/(1+(CY2/CZ2)/((DA2/DB2)^inputs!$G$82)))*VLOOKUP(density,density_inputs,21)	calculates adjustment to buried fraction using standard and local costs in logistic function
DD	wire center	='cluster input data'!A2	repeats wire center location ID from cluster input data
DE	quadrant	='cluster input data'!F2	repeats quadrant number from cluster input data
DF	sign	=VLOOKUP('cluster input data'!G2,inputs!$X$5:$Y$8,2)	determines sign of cluster angular coordinate
DG	angle	=DF2*'cluster input data'!H2	attaches sign to cluster angular coordinate
DH	maincluster angle x radius	=IF(P2=0,DG2*'cluster input data'!I2,0)	calculates distance weighting for angular coordinate of cluster
DI	cumulative product	=IF(AND(DD3=DD2,DE3=DE2),DI3+DH2,DH2)	accumulates weighted angle for feeder route (quadrant)
DJ	main cluster cumulative radius	=IF(AND(DD3=DD2,DE3=DE2),DJ3+IF(P2=0,'cluster input data'!I2,0),IF(P2=0,'cluster input data'!I2,0))	accumulates distance for clusters along feeder route
DK	wtd avg feeder offset angle (no limit)	=IF(OR(DD1<>DD2,DE1<>DE2),DI2/DJ2,0)	calculates feeder steering angle offset to be applied to angular coodinate for each cluster when feeder steering enabled
DL	repeated offset	=IF(fdr_steer_enable,IF(AND(DD1=DD2,DE1=DE2),DL1,DK2),0)	repeats offset angle for each cluster in feeder route (quadrant)
DM	resultant	=ABS(DG2-DL2)	applies offset to angle when feeder steering enable
DN	RT est. annual cost, w/per-line EO adjustments	=IF(P2=0,(BZ2+CB2-BX2*(inputs!$G$101+inputs!$G$102))*(LCFactors!$C$10+LCFactors!$D$10),0)	estimates annual life-cycle cost for remote terminals, including end-office adjustments for DLC per-line investment and MDF savings
DO	copper cable est. annual cost	=IF(P2=0,lines_adj*E2*inputs!$G$100/VLOOKUP(density,inputs!$F$89:$G$97,2)*(CE2*(LCFactors!$C$5+LCFactors!$D$5)+CD2*(LCFactors!$C$3+LCFactors!$D$3)+CF2*(LCFactors!$C$7+LCFactors!$D$7)),0)	estimates annual life-cycle cost for copper feeder cable to serve cluster
DP	fiber cable est. annual cost	=IF(P2=0,E2*CC2*inputs!$G$99*(CD2*(LCFactors!$C$4+LCFactors!$D$4)+CE2*(LCFactors!$C$6+LCFactors!$D$6)+CF2*(LCFactors!$C$8+LCFactors!$D$8)),0)	estimates annual life-cycle cost for fiber feeder cable to serve cluster
DQ	cumulative cable and structure investment	=IF(CG3=CG2,DQ3+AO2+AP2+AQ2+AS2+AT2+AU2+AV2,AO2+AP2+AQ2+AS2+AT2+AU2+AV2)	accumulates cable and structure investment for cluster and outliers to determine total per-line investment for cluster/outlier system
DR	cumulative DLC and T1 investment	=IF(CG3=CG2,DR3+BZ2+CB2+BP2+BS2,BZ2+CB2+BP2+BS2)	accumulates T1 investment for outliers to determine total per-line investment for cluster/outlier system

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Equation Listing

HAI Model, v5.0A
Distribution Module

Column	Name	Formula	Description
DS	cumulative SAI investment	=IF(CG3=CG2,DS3+BD2+BG2,BD2+BG2)	accumulates SAI investment for cluster and outliers to determine total per-line investment for cluster/outlier system
DT	terminal investment	=IF(calculations!BH2=0,lines_adj*VLOOKUP(density,density_inputs,16),0)	calculates terminal investment for cluster or outlier
DU	cumulative terminal investment	=IF(CG3=CG2,DU3+DT2,DT2)	accumulates terminal investment for cluster and outliers to determine total per-line investment for cluster/outlier system
DV	drop investment	=IF(calculations!BH2=1,0,VLOOKUP(density,density_inputs,17)*('cluster input data'!AB2+'cluster input data'!AD2+'cluster input data'!AE2+'cluster input data'!AF2+'cluster input data'!AG2+'cluster input data'!AL2+'cluster input data'!AM2)+VLOOKUP(density,density_inputs,15)*('cluster input data'!X2-'cluster input data'!AB2+'cluster input data'!AA2+SA_loops+IF('cluster input data'!AC2=0,0,('cluster input data'!AH2+'cluster input data'!AI2+'cluster input data'!AJ2+'cluster input data'!AK2)/'cluster input data'!AC2*'cluster input data'!Y2)))	computes drop investment for cluster or outlier
DW	cumulative drop investment	=IF(CG3=CG2,DW3+DV2,DV2)	accumulates drop investment for cluster/outlier system
DX	NID investment	=IF(calculations!BH2=0,hh_tot*inputs!$C$30+'cluster input data'!Y2*inputs!$C$32+('cluster input data'!X2+SA_loops)*(inputs!$C$35/inputs!$C$38+inputs!$C$36)+(inputs!$C$35+inputs!$C$36)*'cluster input data'!AA2,NID_indoor*lines_adj)	computes NID investment for cluster or outlier
DY	cumulative NID investment	=IF(CG3=CG2,DY3+DX2,DX2)	accumulates NID investment for cluster/outlier system
DZ	cumulative lines	=IF(CG3=CG2,DZ3+lines_adj,lines_adj)	accumulates total line count for cluster/outlier system
EA	total distribution investment per line	=IF(AND(P2=0,DZ2>0),(DQ2+DR2+DS2+DU2+DW2+DY2)/DZ2,0)	computes total per-line investment for distribution plant and equipment
EB	wireless cap indicator	=IF(AND(wireless_cap_enable,P2=0,clustr_tot_lines<=brdcast_lines_max),IF(EA2>IF(clustr_tot_lines<=brdcast_thresh,wireless_cap,brdcast_common_inv*CEILING(clustr_tot_lines/brdcast_lines_max,1)/clustr_tot_lines+brdcast_var_inv),1,0),0)	when wireless cap enabled, compares total per-line distribution investment to estimated wireless technology investment and indicates when wireless estimate is less than wireline
EC	repeated wireless cap indicator	=IF(CG1=CG2,EC1,EB2)	repeats wireless cap indicator for all outliers in cluster/outlier system
ED	maximum outlier dimension, ft	=IF(P2=1,5280*MAX(SQRT('cluster input data'!O2*aspect),SQRT('cluster input data'!O2/aspect)),0)	computes maximum outlier dimension in feet using input outlier area and aspect ratio

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Distribution Module

Column	Name	Formula	Description
EE	outlier subscriber road cable adjustment to average loop length wtd by lines	=IF(P2=1,IF(CU2<=1.0,IF(CU2<=2,0.5*ED2,IF(CU2<=3,5*ED2/12,1.5*ED2)))*CU2,0)	computes average distance from outlier center to subscribers served by subscriber road cable, wtd by lines in outlier
EF	cumulative weighted outlier adjustment	=IF(CG3=CG2,EF3+EE2,EE2)	accumulates weighted outlier adjust across all outliers in cluster
EG	weighted average outlier subscriber road cable adjustment	=IF(OR(P2=1,'cluster input data'!AR2=0),0,EF2/'cluster input data'!AR2)	computes wtd average adjustment for cluster

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Worksheet: **output**

Equation Listing

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Distribution Module

Column	Name	Formula	Description
A	company	='cluster input data'!B2	reports operating company name
B	operating company indicator	='cluster input data'!C2	reports operating company type indicator from 'cluster input data'
C	wire center	='cluster input data'!A2	reports 8-character location identifier (specifies wire center)
D	CBG number	=IF(calculations!P2=0,'cluster input data'!D2,0)	reports principal CBG identifier for cluster
E	quadrant	=IF(calculations!P2=0,'cluster input data'!F2,0)	reports which wire center quadrant the cluster falls in
F	main feeder distance, ft	=calculations!C2	reports main feeder distance, modified by difficult terrain or route/air multiplier as required
G	subfeeder cable distance, ft	=calculations!D2	reports subfeeder cable distance, modified by difficult terrain distance multiplier if required
H	total distribution route distance in cluster, ft	=calculations!BU2	reports total structure distance for distribution plnnt
I	total lines	=lines_adj	reports total line count, including adjusted special access lines, public lines, business and residential lines
J	density -- lines/sq mi	=IF(calculations!P2=0,'cluster input data'!R2,0)	reports density expressed as total lines per sq mi of cluster or outlier area
K	area, sq mi	='cluster input data'!O2	reports cluster or outlier area in sq mi
L	business lines	='cluster input data'!X2	reports total business lines, including single- and multi-line service
M	residential lines	='cluster input data'!Y2	reports total residential lines, including first and multiple lines
N	individual SA lines -- VG/DS-0 equiv	=SA_loops	reports special access total voice grade/DS0 equivalents
O	public lines	='cluster input data'!AA2	reports total public lines
P	households	='cluster input data'!AC2	reports total households in cluster or outlier
Q	single-line business lines	='cluster input data'!AB2	reports total single-line business lines; total included in business line count
R	distribution cable inv, underground	=IF(wireless_cap_ind=0,calculations!AO2,0)	reports total investment in underground distribution cable
S	distribution cable inv, buried	=IF(wireless_cap_ind=0,calculations!AP2,0)	reports total investment in buried distribution cable
T	distribution cable inv, aerial	=IF(wireless_cap_ind=0,calculations!AQ2,0)	reports total investment in aerial distribution cable

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Equation Listing

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Distribution Module

Column	Name	Formula	Description
U	distribution conduit inv	=IF(wireless_cap_ind=0,calculations!AU2,0)	reports total investment in distribution conduit materials
V	distribution conduit placement inv	=IF(wireless_cap_ind=0,calculations!AV2,0)	reports total investment in distribution conduit placement
W	distribution poles inv	=IF(wireless_cap_ind=0,calculations!AS2,0)	reports total investment in distribution poles and pole setting
X	distribution buried placement inv	=IF(wireless_cap_ind=0,calculations!AT2,0)	reports total investment in distribution buried cable placement
Y	rock plcmt mult	=IF(calculations!P2=0,rock_mult,0)	reports rock placement multiplier to be used by feeder module in modifying placement investment as may be required by shallow bedrock conditions
Z	difficult surface mult	=IF(calculations!P2=0,diff_sfc,0)	reports difficult surface placement multiplier to be used by feeder module in modifying placement investment as may be required by difficult surface conditions
AA	water table depth, ft	=IF(calculations!P2=0,'cluster input data'!V2,0)	reports water table depth for use by feeder module in modifying manhole investment in presence of high water table
AB	effective distribution fill	=IF(AND(wireless_cap_ind=0,calculations!P2=0),(0.5*calculations!R2/(calculations!S2*calculations!U2)/(calculations!AA2+calculations!AB2*max_cable)),0)	reports achieved distribution cable fill factor as computed at distribution side of SAI
AC	number of high-density RTs	=IF(wireless_cap_ind=0,IF(calculations!F2=1,calculations!CA2,0),0)	reports total high-density remote terminals required in cluster; includes effects of branch or backbone subdivision, if required
AD	high-density RT investment	=IF(wireless_cap_ind=0,IF(calculations!F2=1,calculations!CB2,0),IF(calculations!P2=0,IF(clustr_tot_lines<=brdcast_thresh,clustr_tot_lines*wireless_cap,brdcast_common_inv*CEILING(clustr_tot_lines/brdcast_lines_max,1)+brdcast_var_inv*clustr_tot_lines),0))	reports total investment in high-density DLC remote terminals for cluster; computes representative wireless investment totals if wireless "cap" calculations are enabled and local distribution investment exceeds either point-to-point or broadcast "cap"
AE	number of low-density DLC RTs	=IF(wireless_cap_ind=0,IF(calculations!F2=1,calculations!BY2,0),0)	reports total low-density remote terminals required in cluster; includes effects of branch or backbone subdivision, if required
AF	low-density DLC and T1 road terminal and repeater investment	=IF(wireless_cap_ind=0,IF(calculations!F2=1,calculations!BZ2,0)+calculations!BP2*calculations!AK2+calculations!BS2,0)	reports investment in low-density DLC remote terminals and in T1 equipment for outliers

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Distribution Module

Column	Name	Formula	Description
AG	fiber strands required	=IF(wireless_cap_ind=0,IF(calculations!F2=1,calculations!CC2,0),IF(calculations!P2=0,4,0))	reports total fiber strands needed by RTs in cluster; if wireless cap exceeded, reports four fibers for radio equipment
AH	SAI investment	=IF(wireless_cap_ind=0,calculations!BD2+calculations!BG2,0)	reports total SAI investment for cluster, including indoor SAI totals when high-rise calculations are invoked
AI	terminal investment	=IF(wireless_cap_ind=0,calculations!DT2,0)	reports total investment in terminals (interface between drops and distribution cable)
AJ	drop investment	=IF(wireless_cap_ind=0,calculations!DV2,0)	reports total investment in installed subscriber drops
AK	NID investment	=IF(wireless_cap_ind=0,calculations!DX2,0)	reports total investment in network interface devices
AL	number of DLC lines	=IF(AG2=0,0,calculations!DZ2)	reports total number of lines served by DLC in cluster and outliers
AM	vertical connecting cable length, ft	=IF(wireless_cap_ind=0,calculations!AW2,0)	reports vertical (optical fiber) connecting cable to feeder module for sizing and investment computation when backbone cable is subdivided
AN	horizontal connecting cable length, ft	=IF(wireless_cap_ind=0,calculations!AX2,0)	reports horizontal (optical fiber) connecting cable to feeder module for sizing and investment computation when branch cables are subdivided
AO	vertical connecting structure distance, ft	=IF(wireless_cap_ind=0,calculations!AY2,0)	reports structure distance for vertical connecting cable, when present
AP	horizontal connecting structure distance, ft	=IF(wireless_cap_ind=0,calculations!AZ2,0)	reports structure distance for horizontal connecting cable, when present
AQ	average loop length in cluster, ft	=IF(wireless_cap_ind=0,calculations!BT2,0)	reports average loop length within cluster
AR	maximum loop length, ft	=IF(wireless_cap_ind=0,calculations!BV2,0)	reports maximum loop length in cluster
AS	cluster ID	='cluster input data'!E2	repeats cluster ID from cluster input sheet
AT	cluster serial number	=calculations!CG2	reports basic cluster serial number without outlier extensions for use by interface in totalling cluster investments
AU	wireless cap indicator	=IF(calculations!P2=0,wireless_cap_ind,0)	reports whether wireless cap is reached for cluster; saved in workfile
AV	lines affected by wireless cap	=IF(AND(AU2=1,calculations!P2=0),calculations!DZ2,0)	If wireless cap applies, records total lines in cluster and outliers; save in workfile
AW	cable+structure+DLC inv less wireless estimate	=IF(AND(AU2=1,calculations!P2=0),calculations!EA2-output!AD2,0)	calculates investment saved by employment of wireless assumptions